# FEEDING HABITS OF THE BONNETHEAD SHARK, *SPHYRNA TIBURO*, FROM NORTHERN BRAZIL

by

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**ABSTRACT**. - Feeding habits of the bonnethead shark, *Sphyrna tiburo* were investigated through analysis of stomach contents of specimens collected in shallow waters in northern Brazil (Maranhão State). The diet is dominated by crustaceans, consisting mainly of three species of *Callinectes* crabs. The species shows a specialist behaviour, preying on few prey items. The percentage of empty stomachs is similar to those recorded in the Northern Hemisphere. Males and females show a similar food spectrum. No important dietary shift was associated with size. However, the importance of *Callinectes* in food contents differs with size and sex. Size selectivity of prey was not observed. Mean prey weight increased in females up to 90 cm, whereas in males it decreased with length up to 80 cm. Males have less food in their stomachs than females.

**RÉSUMÉ**. - Régime alimentaire du requin marteau *Sphyrna tiburo* du nord du Brésil.

Le régime alimentaire du requin marteau tiburo (*Sphyrna tiburo*) a été déterminé par l'analyse des contenus stomacaux d'individus pêchés dans les eaux peu profondes de la région Nord du Brésil. Le régime alimentaire est dominé par les crustacés et particulièrement par trois espèces de crabes *Callinectes*. Ce requin montre un comportement alimentaire spécialisé, ne recherchant que quelques types de proies. Le pourcentage d'estomacs vides est comparable à ce qui a été décrit dans l'Hémisphère Nord. Les mâles et les femelles ont des proies similaires. Aucun changement important de régime alimentaire n'est associé à la croissance. La proportion des proies (*Callinectes*) dans les contenus stomacaux varie avec la taille du prédateur, mais aucune relation entre la taille des proies et la taille des prédateurs n'a pu être établie. Le poids moyen des proies augmente chez les femelles jusqu'à une taille inférieure à 90 cm, tandis que, chez les mâles, ce poids diminue avec la taille. Les contenus stomacaux des mâles sont moindres que ceux des femelles.

Key-words. - Sphyrnidae, *Sphyrna tiburo*, ASW, Brazil, Shark diet, Feeding habits.

*Sphyrna tiburo* is a placentaly viviparous shark species abundant in the western Atlantic where it is reported from North Corolina (USA) to southern Brazil (São Paulo) (Compagno, 1984). It is commonly caught in shallow waters close to estuaries and bays down to 25 m. In northern Brazil, it represents about 10% of the total of elasmobranch catches (Lessa, 1986) landed at São Luis Island (2°30'S, 44°05'W). Several aspects of the biology of northern hemisphere populations have been studied including reproduction (Clark and von Schmidt, 1965; Parsons, 1993a; Manire *et al.*, 1995), behaviour (Myrberg and Gruber, 1974), placentation (Hamlett, 1986), age and growth (Parsons, 1993b) and diet and feeding habits (Cortés *et al.*, 1996). Likewise, information on sexual develop-

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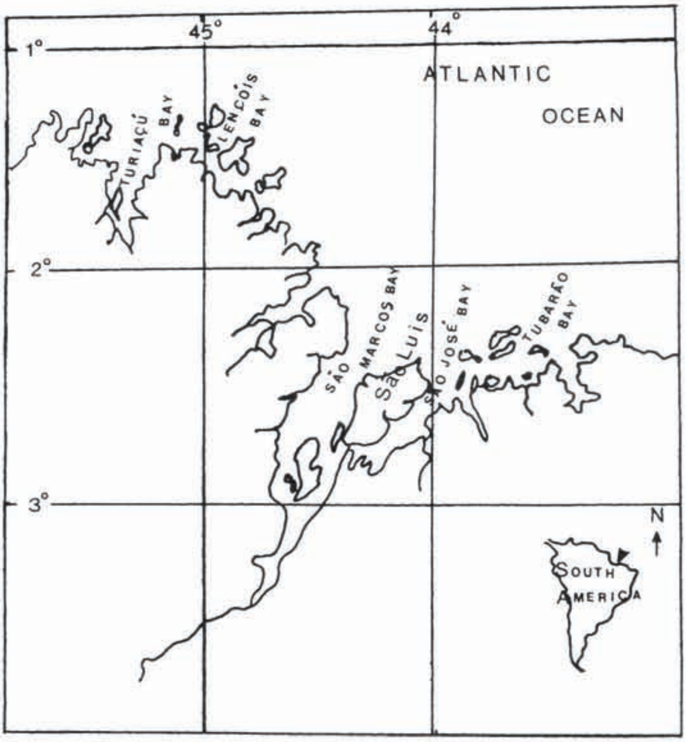

Fig. 1. - Fishery grounds of *Sphyrna tiburo* in Maranhão State, northern Brazil.

ment, reproductive cycles and biometry of this species in southern Atlantic is also available (Lessa, 1988; Silva and Lessa, 1991; Lessa and Silva, 1992).

However no information is available on the feeding habits of this species in the southern Atlantic, where it is referred to by fishermen as "caranguejeira" or crab eater. The aim of this paper is to present a qualitative and quantitative analysis of stomach contents considering sex, seasonality, sizes of the bonnethead sharks from the Maranhão State Coast, in northern Brazil.

## MATERIAL AND METHODS

Samples were obtained at two-week intervals in the western part of Maranhão State, in the area between Tubarão Bay and Lençois Bay (1°05'-2°45'S, 43°30'-45°W) (Fig. 1) from June 1984 to August 1986. The coastline is low-lying with mangrove and deeply indented because of the large number of rivers, islands, estuaries and cliffs, where tidal amplitudes may reach 7 m. This region is under the Amazonic influence, the rainy season being from December to May and the dry season, from June to November (Stride *et al.*, 1992). Salinity during sample collection ranged from 20.0 to 34.41‰. Drift nets, 900 m in length, 7.2 m in height, with a stretched mesh size of 8.0 cm between opposed knots were deployed from sailing boats targeting the Brazilian Spanish Mackerel *Scomberomorus brasiliensis*, in shallow waters (16 to 40 m).

The overall sample was obtained over 31 fishing trips. From each specimen was recorded: total length (TL, cm) (Compagno, 1984), total and gutted weights (g), weight of stomachs with contents (g), weight of empty stomachs (g), number of prey in each stomach. Dietary contents were analysed to the lowest possible taxon or category, depending on the digestion stage of each item. Inidentifiable prey were placed in the "others" category.

Crabs and shrimps were identified following Williams (1965), or compared to a reference collection deposited at Universidade Federal de Pernambuco. Teleosts present in stomach contents were identified following Figueiredo (1977), Figueiredo and Menezes (1978), or comparing otoliths to a reference collection when prey were in advanced stages of digestion (Saul and Lessa, 1991).

For assessment of the importance of prey items, the percentage Index of Relative Importance (%IRI), after King (1984) and Cortés *et al.* (1996), was used. This index combines prey number, weight and occurrence (Hyslop, 1980). According to King (1984), feeding intensity was assessed by the mean number and mean weight of prey per stomach expressed as a percentage of body weight.

All references to length at birth, maturity or reproductive stages made throughout this paper follow information presented by Silva and Lessa (1991) and Lessa and Silva (1992). As found by these authors, individuals are born at less than 35 cm TL, from birth to 69 cm females are considered immature, from 70-90 cm, when vitellogenesis starts,

Table I. - Diet composition of the bonnethead shark *Sphyrna tiburo* in the Maranhão State Coast expressed as percent by number (%N), percent weight (%W), frequence of occurrence (%O) and percentage index of relative importance (%IRI).

| Prey items | %N | %W | %O | %IRI |
|---|---|---|---|---|
| **Crustacea** | 87.91 | 88.53 | 86.24 | 92.79 |
| **Portunidae** | | | | |
| ***Callinectes ornatus*** | 28.92 | 37.22 | 27.52 | 42.89 |
| ***Callinectes exasperatus*** | 21.04 | 36.73 | 31.19 | 33.51 |
| ***Callinectes* sp.** | 20.37 | 13.75 | 22.94 | 16.01 |
| **Penaeidae** | | | | |
| ***Xyphopenaeus kroyerii*** | 10.99 | 0.35 | 0.92 | 0.14 |
| **Unidentified shrimp** | 5.49 | 0.33 | 2.75 | 0.22 |
| **Pallinuridae** | | | | |
| ***Panulirus argus*** | 1.10 | 0.15 | 0.92 | 0.02 |
| **Mollusca** | 1.10 | 0.05 | 0.92 | 0.01 |
| **Unidentified gastropod** | 1.10 | 0.05 | 0.92 | 0.01 |
| **Osteichthyes** | 5.50 | 9.33 | 4.58 | 6.89 |
| **Engraulidae** | 2.20 | 1.82 | 1.83 | 0.7 |
| **Congridae** | 1.10 | 4.18 | 0.92 | 2.05 |
| **Scianidae** | | | | |
| ***Macrodon ancylodon*** | 2.20 | 3.33 | 1.83 | 4.14 |
| **Annelida** | 5.49 | 0.08 | 3.67 | 0.28 |
| **Polychaeta** | | | | |
| ***Hoplunus tenius*** | 5.49 | 0.08 | 3.67 | 0.28 |

they are considered adolescents and from 90 cm on the size at which pregnancy was for the first time observed, females are considered adults. In turn, males smaller than 59 cm are considered immature, individuals from 60 to 79 cm are considered adolescents, and those larger than 80 cm are adults.

Percent IRI, mean prey weight, and mean number of prey were examined in relation to length, quarters of the year and reproductive stages (females). For inferences on feeding strategy, the modified Costello graphical method (Costello, 1990), as proposed by Amundsen *et al.* (1996), was followed. Seasonality in the diet was studied considering quarters 1, 2, 3, and 4. Quarter 1 corresponds to January, February and March; quarter 2 to April, May and June, and so forth.

Except for qualitative analysis and diversity index calculations, prey items were pooled into five categories: *Callinectes ornatus*, *C. exasperatus*, *Callinectes* sp., Penaeidae, and miscellaneous prey items such as fish, squid, molluscs and other crabs were included in the "other" category. The Shannon measure with evenness (J') was used to compare male and female diets (Brower and Zar, 1984). It was calculated taking into account the numbers of individuals in each taxon or category listed in table I.

Mean prey weight (% of body weight) and mean prey number were subjected to the Kruskal-Wallis test. If a significant difference was found, comparisons were performed using the Mann-Whitney *U*-test (Siegel, 1981). The Kolmogorov-Smirnov test was used to to compare two independent (male and female) length frequency distributions. Chi-squared tests with Yate's correction for differences between males and females numbers in the overall sample was used (Browner and Zar, 1984). Throughout this paper, unless otherwise mentioned, size refers to total length (Compagno, 1984).

## RESULTS

### The sample and diet composition

Of 203 shark stomachs examined, 191 specimens contained food [101 were males (38 to 96 cm) and 90 females (35.6 to 125 cm)] and 12 were empty (6.28%).

Of these, 72 females and 82 males were adolescents and adults, and the remaining 37 individuals were juveniles (Silva and Lessa, 1991). Males were dominant in the sample in length classes ranging from birth up to 90 cm, whereas females outnumbered males in larger classes (Fig. 2). Significant differences were not found between males and females in the overall sample ($\chi^2$ with Yate's correction = 0.635; $p > 0.05$). However, length frequency distributions by sex compared using the Kolmogorov-Smirnov test, indicated that differences were significant (Dmax = 51.193, df = 2, $p < 0.05$).

Crustaceans were the main prey according to all indices and were represented mainly by three prey items: *Callinectes ornatus, Callinectes exasperatus* and *Callinectes* sp. (Table I). A similar spectrum of items was found in both sexes, however the Shannon measure with evenness was lower in females (J' = 0.672) than in males (J' = 0.727).

### Size-based feeding intensity and %IRI

Mean weight of prey as a percentage of body weight for males decreased from ~ 5% in 50 cm juveniles to 3.7% in 80 cm adults (Fig. 3A). The maximum mean prey weight was reached in 90 cm adult males. Significant differences in mean prey weight were detected with size (Kruskal-Wallis, $p < 0.05$).

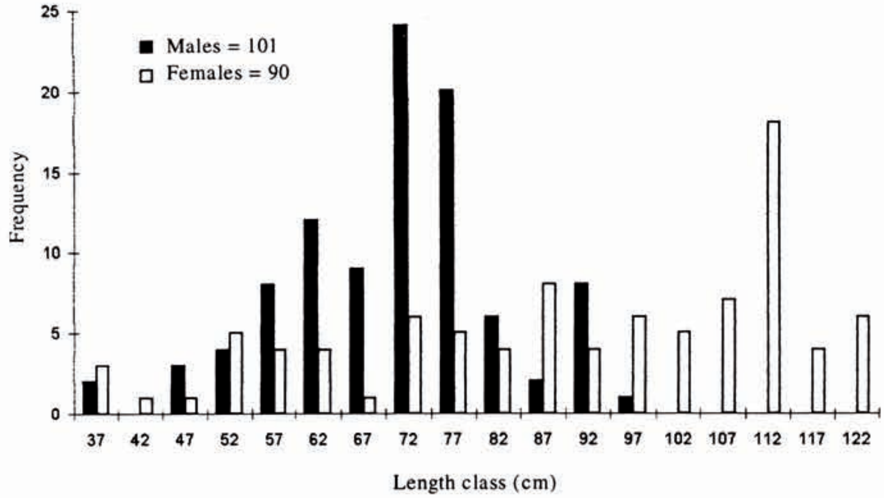

Fig. 2. - Length frequency distribution of *Sphyrna tiburo* collected from 1984 to 1986 in Maranhão State, northern Brazil.

Mean prey number for males varied from 1.5 to 6.5 prey in the whole sample (Fig. 3B), a significant variation (Kruskal-Wallis; $p < 0.05$). The highest mean number was observed for 70 cm individuals, decreasing both in smaller and larger specimens. Differences in mean prey number between 60 and 70 cm length classes were significant, as were those between 70 cm and 90 cm length classes (Mann-Whitney *U*-test, $p < 0.05$).

The index of relative importance, analysed on the basis of the five prey categories, showed that *Callinectes* sp. was the most important item for individuals ranging from 50 to 80 cm (Fig. 3C). *Callinectes ornatus* and *C. exasperatus* together represented 30-40% IRI in 60-70 cm individuals. *C. exasperatus* was the most important item for 90 cm adult individuals, with a IRI of 100%.

In females, prey weight ranged from 3% of the body weight in 50 cm juveniles to 7.5% in 90 cm adult specimens (Fig. 4A). Significant variation in prey weight was detected with size (Kruskal-Wallis, $p < 0.05$) due to a decrease in 90-100 cm adult females (Mann-Whitney *U*-test, $p < 0.05$), followed by an increase in 110-120 cm specimens. The mean number of prey ranged from 2 items in juveniles to ~ 6 in fully adult 110 cm females (Fig. 4B). Mean number of prey showed a decreasing tendency for individuals between 70 and 100 cm. Mean prey number variation with size was significant (Kruskal-Wallis, $p < 0.05$) due to differences between 70 cm and 100 cm individuals and between 100 cm and 110 cm specimens (Mann-Whitney *U*-test, $p < 0.05$).

Variation in %IRI with size (Fig. 4C) showed that *Callinectes* sp. made up 100% IRI in juveniles, decreasing in larger individuals where *C. exasperatus* and *C. ornatus* were the most important prey items. Penaeidae, and other prey represented a small portion of the diet in individuals larger than 80 cm.

### Seasonality in feeding intensity and %IRI

Because few females were caught from March to May, both sexes were treated together. Mean prey weight varied from about 5% to 5.5% (Fig. 5A). The Kruskal-Wallis

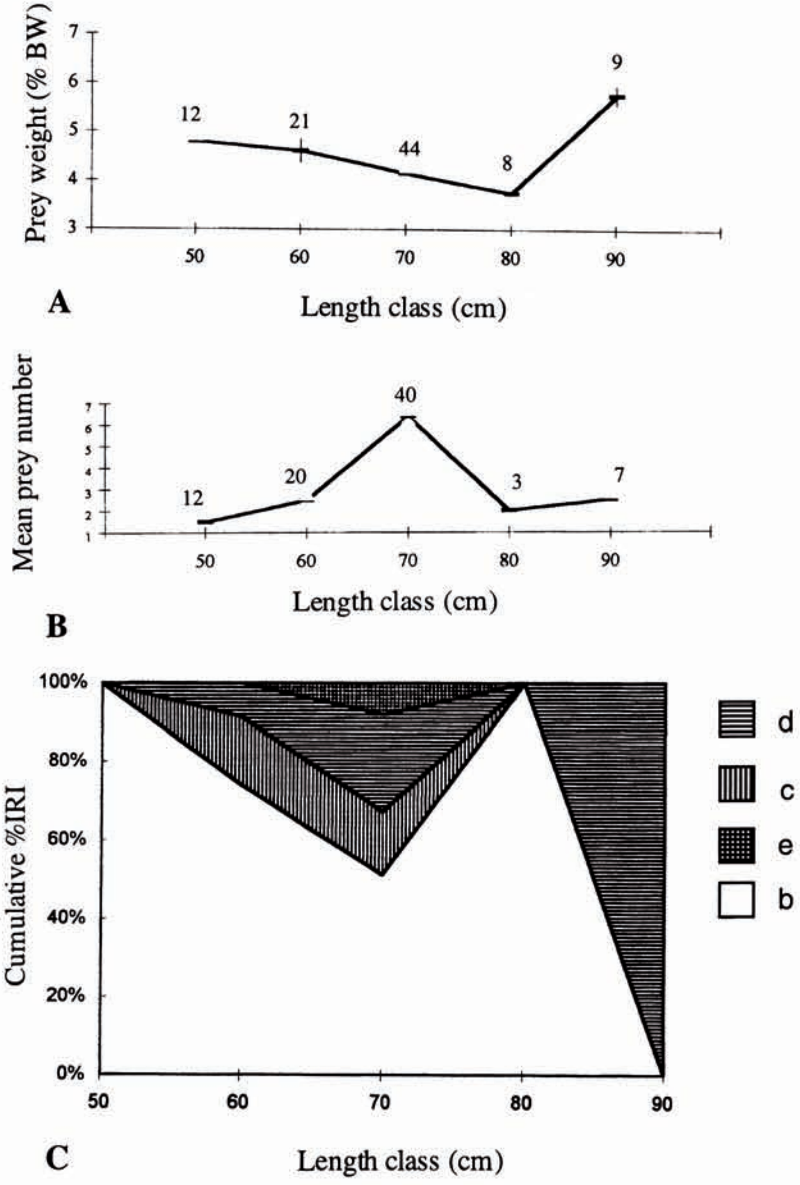

Fig. 3. - Feeding intensity. Prey weight (% of the body weight-BW) (A), prey number (B) and %IRI (C) in males of *Sphyrna tiburo* by length class. Sample sizes given in the figure and bars indicate S.E. (A and B). Legends of figure 3C correspond to: **a**: others; **b**: *Callinectes* sp.; **c**: *C. ornatus*; ***d***: *C. exasperatus*; **e**: Penaeidae.

test did not reveal any significant differences among quarters ($p > 0.05$). In contrast, mean prey number varied from 4 items in quarter 1 to 7 items in quarter 3, with only 2 items found in quarter 2 (Fig. 5B). The Kruskal-Wallis test indicated significant differ-

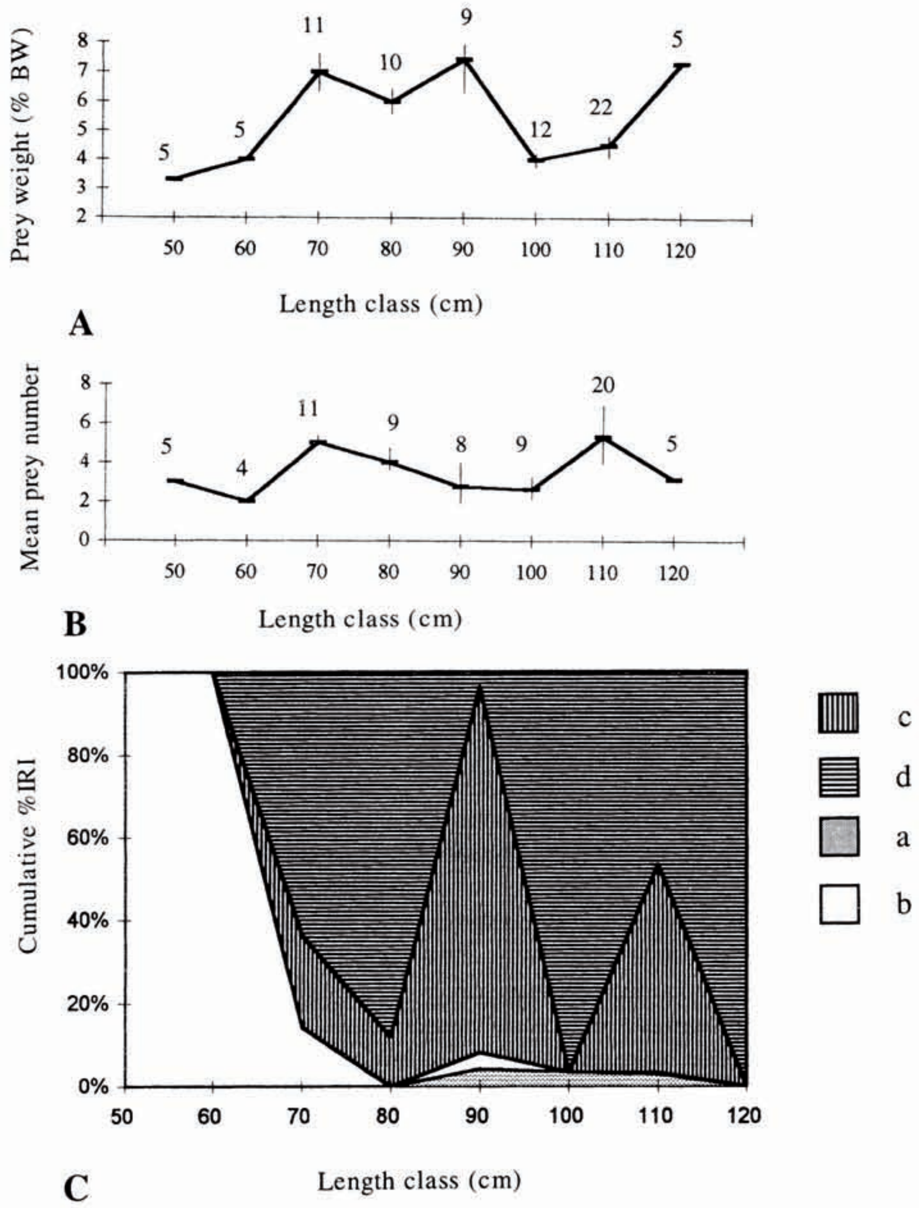

Fig. 4. - Feeding intensity. Prey weight (% of the body weight, BW) (A), prey number (B) and %IRI (C) in females of *Sphyrna tiburo* by length class. Sample sizes given in the figure and bars indicate S.E. (A and B). Legends of figure 4C correspond to: **a**: others; **b**: *Callinectes* sp.; **c**: *C. ornatus*; ***d***: *C. exasperatus*.

ences in mean number of prey over the year ($H = 9.34$, $df = 3$, $p < 0.05$) attributable to differences between the second and third quarters, and between the third and fourth

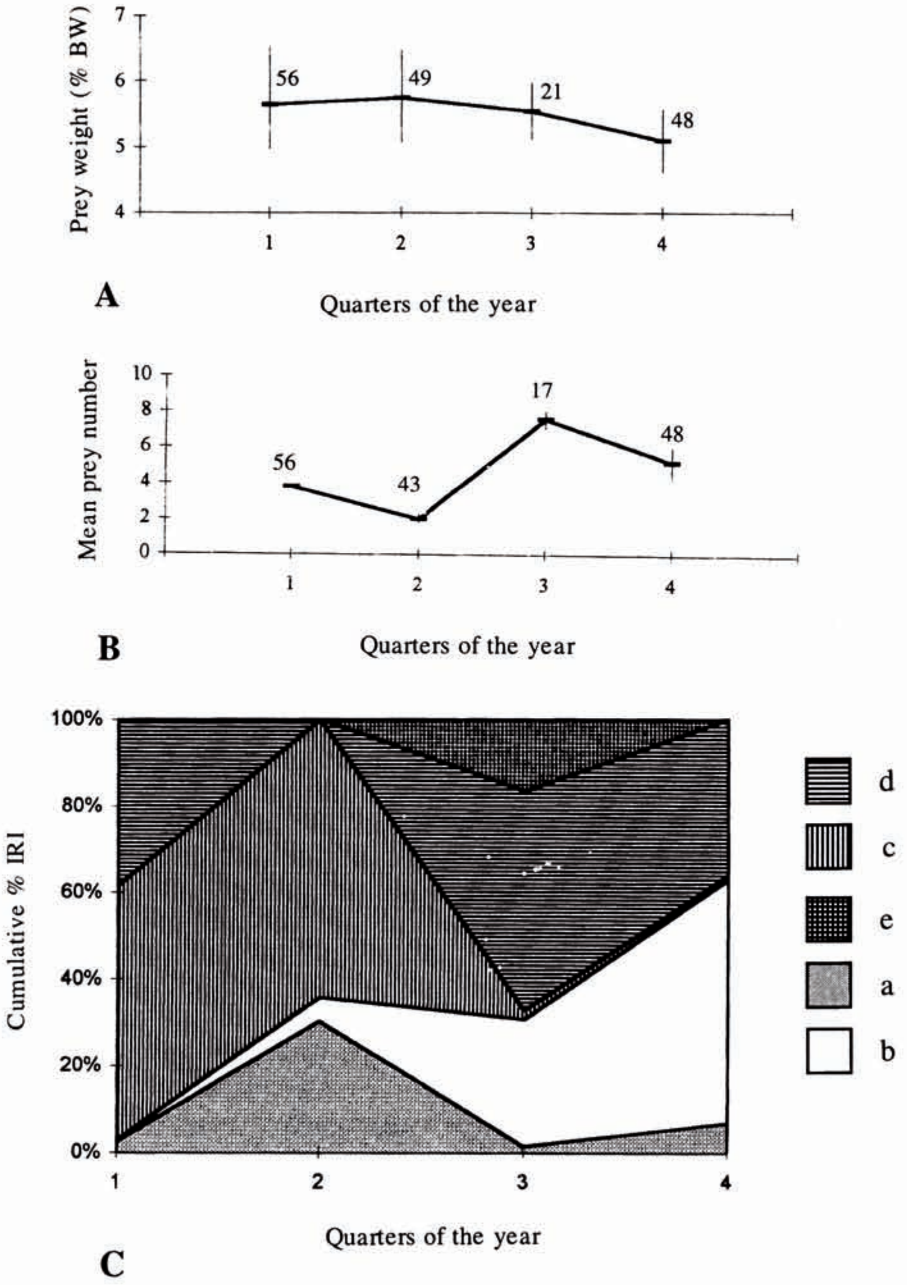

Fig. 5. - Feeding intensity: Prey weight (% of the body weight) (A), prey number (B) and %IRI (C) in both sexes of *Sphyrna tiburo* by quarters of the year. Sample sizes given in the figure and bars indicate S.E. (A and B). Legends of figure 5C correspond to: **a**: others; **b**: *Callinectes* sp.; **c**: *C. ornatus*; ***d***: *C. exasperatus*; **e**: Penaeidae.

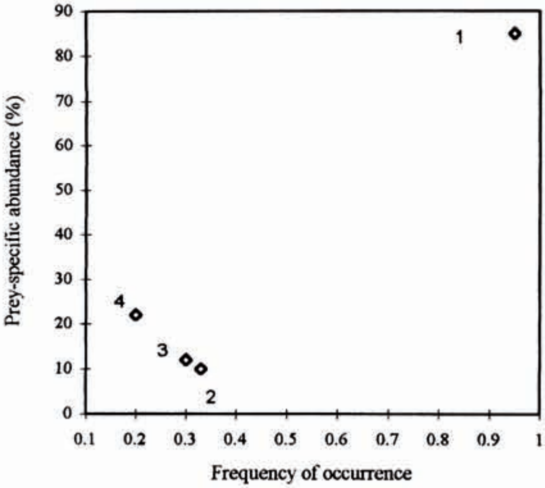

Fig. 6. - Costello's diagram showing prey-specific abundance *versus* frequency of occurrence for *Sphyrna tiburo* on Maranhão coast, northern Brazil. Numbers inside graph correspond to: 1: *Callinectes*, 2: fish, 3: others, 4: Penaeidae.

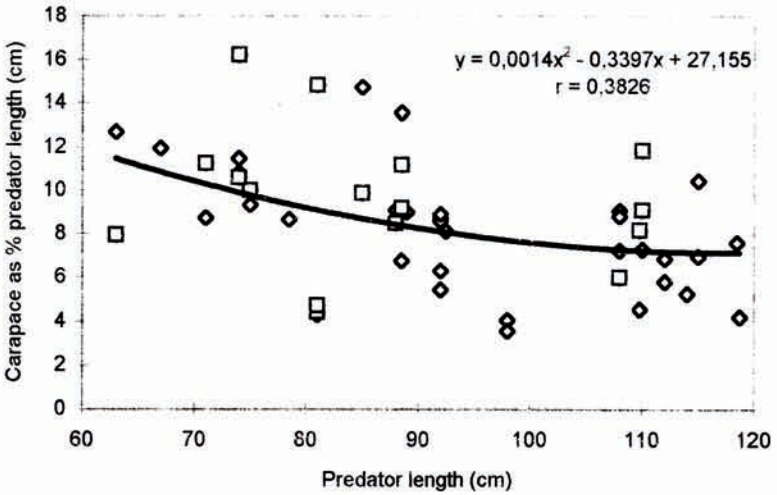

Figure 7. - Prey width / predator length scatterplot for both sexes for *Sphyrna tiburo* on Maranhão Coast, northern Brazil. Diamonds = *C. ornatus*; squares = *C. exasperatus*.

quarters (Mann-Whitney *U*-test, $p < 0.05$). Among the five prey categories considered, *C. ornatus*, *C. exasperatus* and *Callinectes* sp. made up about 80% of the diet during all quarters of the year. Among the remaining items, fish represented about 20% of the diet in the second quarter, whereas Penaeidae made up another 20% of the diet in the third quarter. Other prey items corresponded only to a small portion of the diet in the fourth quarter (Fig. 5C).

### Feeding strategy and prey/predator relationship

A feeding strategy diagram (Fig. 6) showed that *Callinectes* species had the highest values of prey-specific abundance and frequency of occurrence and thus are dominant prey. All other prey types were located in the lower left segment of the diagram, corresponding to low values of prey-specific abundance and low frequency of occurrence and thus, are rare or unimportant species.

A scatterplot of the relationship between predator length (60-118.7 cm) *versus* prey carapace width for *C. exasperatus* and *C. ornatus* showed high dispersion of prey carapace width within a given length class. For a relationship between prey carapace width as a percentage of predator length a low correlation was obtained, when both prey were treated together (Fig. 7). Correlations obtained for each prey species separately were lower than that obtained for both species together.

## DISCUSSION

The bonnethead sharks in the shallow waters of the Maranhão coast are benthic feeders, preying on organisms on the bottom, or buried in sediments. The main prey were crustaceans of three different species of *Callinectes*. These observations are consistent with those from Cortés *et al.* (1996) for the species in Florida where the main prey item was *C. sapidus*. The Shannon measure with evenness, in the study area was lower in females than in males, indicating that the diet is composed of only a few abundant species (Brower and Zar, 1977), characteristic of specialist behaviour.

The percentage of empty stomachs found in the present study (6.3%) was similar to that found in southwestern Florida by Cortés *et al.* (1996) (5%) and to that found in Tampa Bay (7%), also in southmost Florida (Parsons, 1987 cited in Cortés *et al.*, 1996). Cortés *et al.* (1996) remarked that these percentages, were the lowest reported for shark species collected using non-bait methods of capture such as nets (Wetherbee *et al.*, 1990). As found by these authors, in southwest Florida, the low incidence of empty stomachs suggests that *S. tiburo* eats frequently and gastric evacuation is slow relative to feeding frequency.

The modified Costello method for graphical analysis of stomach content data (Amundsen *et al.*, 1996) showed that *S. tiburo* is a specialist predator with a narrow niche width. *S. tiburo* seems to correspond to the third case study presented by Amundsen *et al.* (1996) showing a population specialisation towards one single prey type (*Callinectes*). That is the case when most individuals feed on the dominant prey taxon, but small numbers of other prey types are occasionally included in the diet of some individuals.

Two species of *Callinectes* were the dominant prey in all shark size classes and in all quarters of the year in both sexes. Fish were not observed in the stomach contents of individuals smaller than 70 cm, but apart from this, no important dietary shift was associated with size. However, the participation of *Callinectes* species in food contents differed with sex and size. Unidentified *Callinectes* dominated in juvenile females smaller than 60 cm, perhaps due to faster digestion in smaller sharks. These prey were unidentifiable to species level due to broken carapaces. Identifiable *C. exasperatus* and *C. ornatus* dominated in larger size classes, where the importance of unidentifiable *Callinectes* became minimal. However, in males unidentified *Callinectes* species dominated in all size classes from juveniles to adults and *C. ornatus* were of lesser importance for all length classes, except 90 cm. These results, suggest that digestion in males is faster than in females.

Size selectivity of prey, with larger prey occurring in the diet of larger individuals, as found for *S. tiburo* in southwest Florida (Cortés *et al.*, 1996) could not be demonstrated here. Small and large prey of both *C. ornatus* and *C. exasperatus,* ranging from 3.8 cm to 13 cm in carapace width, were present in stomach contents without any clear pattern.

Cortés *et al.* (1996) found that the median stomach content weight, expressed as percentage of body weight, increased with size in Florida. This pattern would not be expected because daily ration generally decreases with increasing size (Pandian,1967 cited in Cortés *et al.*, 1996). In the present study, an increase in mean prey weight was observed in females up to 90 cm followed by a decrease and subsequent increase for the largest females. However, in males, mean prey weight decreased from 50 cm juveniles to 80 cm adults and dramatically increased in 90 cm adults. The increasing trend observed for females in this study could be explained by a slowing down of digestion as individuals grow and age. This situation is not well documented in elasmobranchs where the opposite, observed partly for males here, is known to happen for most species studied (Cortés *et al.,* 1996). These authors also speculated that males have less food in their stomachs than females because as females grow larger, they eat larger prey which are more difficult and slow to be digested. In contrast, smaller males would eat smaller prey, easier to digest. This reasoning was based on the relationship between predator and prey size, found by these authors but not verified in the present study. Nevertheless males generally showed less food in their stomachs than females even for same-sized individuals.

In summary, we have shown that *Sphyrna tiburo* in northern Brazil has a similar diet to that of Northern Hemisphere populations, showing a specialised strategy, rather homogenous considering sizes and sexes.

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